Kentucky Method 64-511-03
Revised 1/23/03
Supersedes KM 64-511-00
Dated 1/21/00

MOISTURE-DENSITY RELATIONS
(Proctor Density)

Refer to Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5 lb.) Rammer and a 305 mm (12-in.) Drop – AASHTO T 99-01 with the following additions and modifications:

1.3 This test method applies to soil mixtures that have 40 percent or less retained on the No. 4 sieve, when Method A is used, and 30 percent or less retained on the ¾ in. sieve, when method C is used. The material retained on these sieves shall be defined as oversized partilces (coarse particles).

3.1.3. Molds Out of Tolerance Due to Use - A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 100 percent; and the volume of the mold, calibrated in accordance with Section 8 (Calibration of Measure) of AASHTO T 19 is used in the calculations.

4.2. Sieve an adequate quantity of the representative pulverized soil over the No. 4 sieve. If the quantity of material retained on the No. 4 sieve is greater than five percent, follow the procedures outlined in Method C.

8.2. Sieve an adequate quantity of the representative pulverized soil over the ¾ in. and No. 4 sieve. Record the quantity of material retained on the No.4 and ¾ in. sieve. The quantity of material retained on the ¾ inch shall be used to adjust the compacted specimen density to field density in accordance with AASHTO T 224.

14.1.4. In Method C, indicate the quantity of material retained on the No. 4 and ¾ inch sieve.

14.1.6. See figures 1 and 2 for sample data sheets.

SECTION 16 (ADD) -METHOD E PROCEDURE (STABILIZED AGGREGATE BASE)

16.1. Combine in mix percentages representative samples of dry ingredients for the stabilized aggregate base to a sample weight of 6000 grams (a separate sample will be needed for each point desired using a new sample for each compaction test)

16.2. Add water and mix thoroughly to dampen to approximately four percentage points below estimated optimum moisture content. Compact the stabilized aggregate base mixture as in Method A except use the 6-in. mold and 56 blows per layer. Following compaction remove the extension collar; carefully trim the compacted material flush with the top of the mold. In trimming the compacted specimen, holes may develop by removal of coarse particles; these may be patched with fine particles. Weigh the mold inclusive of the compacted material and determine the wet density

according to the procedure described in Section 5.2.1.

16.3. Remove the material from the mold and weigh immediately. Place the entire compacted specimen in an oven and dry to a constant weight to determine the moisture content in accordance with AASHTO T 255.

16.4. Using a new portion of aggregate each time (6000 grams) repeat 5.2 and 5.2.1 for each determination while adding water in approximately 2% increments (120 grams). Continue adding water in increments and compact until there is either a decrease or no change in the weight of the compacted aggregate plus mold.

SECTION 17 (ADD) – Procedure For Field Correction Of Moisture Density Test Results for Variations in Percent Retained on the No.4 Sieve.

17.1. Compacted specimen density determined using Method A or C shall be corrected in accordance with AASHTO T224 for field density purposes if the quantity of plus No. 4 material is greater than 5 percent. The preferred method of determining maximum density of samples with greater than 5% plus No. 4 material is Method C. However, it may be necessary to correct the results of Method A in some cases for oversized particles.

~~1. SCOPE: The following test methods are modifications of AASHTO T 99 and are intended for determining the relation between the moisture content and dry density of materials compacted into a mold with 5.5 lb. rammer dropped from a height of 12 inches. Four methods are provided as follows:~~

~~1.1. Moisture-Density Relations for soils and aggregates with less than 5 percent retained on the No. 4 sieve.~~

~~1.2. Moisture-Density Relations for soils and aggregates with 5 percent or more retained on the No. 4 sieve.~~

~~1.3. Moisture-Density Relations for Cement Treated Sandstone Base.~~

~~1.4. Moisture-Density Relations for Stabilized Aggregate Base.~~

~~2. APPARATUS~~

~~2.1. Molds: New molds shall meet the requirements of AASHTO T99 and shall be specified as such when ordered. The molds shall be solidwall, metal cylinders manufactured with dimensions and capacities shown in Sections 2.1.1 and 2.1.2 below. They shall have a detachable collar assembly approximately 2.375 in. in height, to permit preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material (Note 1). The base plate shall be plane 0.005 in. Refer to AASHTO T 99 for figures for the molds.~~

NOTE 1: Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soils types and the same moisture-density results are obtained. Records of such correlation shall be maintained and readily available for inspection, when alternate types of molds are used.

2.1.1. The molds for Methods 1 and 2 shall be 4 in.molds having a capacity of 0.0333 ± 0.0003 $ft.^3$ with an internal diameter of 4.000 ± 0.016 in. and an internal height, from the base plate to the top of mold, of 4.584 ± 0.005 in.

2.1.2. The molds for Methods 3 and 4 shall be 6 in. molds having a capacity 0.07500 ± 0.00075 $ft.^3$ with an internal diameter of 6.000 ± 0.026 in. and an internal height, from the base plate to the top of mold, of 4.584 ± 0.005 in.

2.1.3. Molds Out of Tolerance Due to Use: A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 100 percent; and the volume of the mold, calibrated in accordance with Section 8 (Calibration of Measure) of AASHTO T 19 is used in the calculations.

2.2. Rammer:

2.2.1. Manually Operated: Metal rammer with a mass of 5.5 ± 0.02 lb., and having a flat circular face of 2.000 ± 0.005 in. diameter with a manufacturing tolerance of 0.01 in. The in-service diameter of the flat circular face shall be not less than 1.985 in. The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of 12.00 ± 0.06 in. above the elevation of the material. The guide-sleeve shall have at least 4 vent holes, no smaller than 3/8 in. diameter spaced approximately 90^o apart and approximately 3/4 in. from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

2.2.2. Mechanically Operated: A metal rammer which is equipped with a device to control the height of drop to a free fall of 12.00 ± 0.06 in. above the elevation of the soil and uniformly distributes such drops to the soil surface (Note 2). The rammer shall have a mass of 5.5 ±0.02 lb., and have a flat circular face of 2.000 in. diameter with a manufacturing tolerance of ± 0.01 in.. The in-service diameter of the flat circular face shall be not less than 1.985 in. The mechanical rammer shall be calibrated by ASTM D 2168.

NOTE 2: It may be impractical to adjust the mechanical apparatus so the free fall is 12 in. each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 12-in. drop is determined. Subsequent blows on the layer of soil being compacted may all be applied by dropping the rammer from a height of 12 in. above

the initial-setting elevation; or, when the mechanical apparatus is designed with a height adjustment for each blow, all subsequent blows should have a rammer free fall of 12 in. measured from the elevation of the soils as compacted by the previous blow. A more detailed calibration procedure for laboratory mechanical-rammer soil compactors can be found in ASTM D 2168.

2.2.3. Rammer Face: The circular face rammer shall be used but a sector face may be used as an alternative provided the report shall indicate type of face used other than the 2 in. circular face and it shall have an area equal to that of the circular face rammer.

2.3. Sample Extruder: A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

2.4. Balances and Scales: A balance or scale conforming to the requirements of AASHTO M 231, Class G 20. Also, a balance conforming to the requirements of AASHTO M 231, Class G 2.

NOTE 3: The capacity of the metric balance or scale should be approximately 11.5 kg when used to weigh the 6 in. mold and compacted, moist soil; however, when the 4 in. mold is used, a balance or scale of lesser capacity than the 11.5 kg may be used, if the sensitivity and readability is 5 g.

2.5. Drying Oven: A thermostatically controlled drying oven capable of maintaining a temperature of 230 ± 9 °F or a household-type microwave oven, preferably with a vented chamber; the required size and power rating of the oven is dependent on its intended use.

2.6. Straightedge: A hardened-steel straightedge at least 10 in. in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. or 0.1 percent of length within the portion used for trimming the soil (Note 4).

NOTE 4: The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.01 in. per 10 in. or 0.1 percent of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil with the cutting edge will cause a concave soil surface.

2.7. Sieves: 2 in., 1 in., 3/4 in., and No. 4 sieves conforming to the requirements of AASHTO M 92, Sieves for Testing Purposes.

2.8. Mixing Tools: Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

2.9. Containers: Suitable containers made of material resistant to corrosion and not subject to

change in weight or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

3. SAMPLE PREPARATION:

3.1. If the sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus where temperature control is such that the sample temperature does not exceed 140°F. Aggregates of stone, slag, or gravel may be oven dried 230 ± 9°F. Then thoroughly break up any aggregations in such a manner as to avoid reducing the natural size of the individual particles.

3.2. For Methods 1 and 2 the sample shall be sieved over a 2 inch and No. 4 sieve. Material retained on the 2-in. sieve shall be discarded. If the quantity of material passing the 2 inch and retained on the No. 4 sieve is less than 5 percent of the total weight of the sample follow the procedure as outlined in Method 1. If the quantity of material is greater than 5 percent, sieve the material retained on the No.4 over a 3/4 inch sieve and follow the procedure as outlined in Method 2.

4. METHOD 1 PROCEDURE: (Modified from AASHTO T 99 METHOD A)

4.1. Weigh a minimum of 3000 grams of minus No. 4 material. Mix the sample with sufficient water to dampen it to approximately four percentage points below optimum moisture content.

4.2. Form a specimen by compacting the prepared material in the 4-inch mold (with collar attached) in three equal layers to give a total compacted depth of about 5 inches. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 inches above the material. During compaction, the mold shall rest on a uniform, rigid foundation (Note 5).

Note 5: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete weighing not less than 200 lb., supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and concrete pavements.

4.3. Following compaction, remove the extension collar, carefully trim the compacted material even with the top of the mold with a straight edge, and weigh the mold and moist soil in kilograms to the nearest 5 grams, or weigh in pounds to the nearest 0.01 lb. For molds conforming to tolerances given in Section 2.1.1 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, or by 0.06614 where the weights are determined in grams, and record the result as the wet density, W_4, in pounds per cubic foot, of compacted material. For used molds out of tolerance by not more than 100 percent (2.1.3), use the factor for the mold as determined in

accordance with Section 8 (Calibration of Measure), AASHTO T 19.

4.4. Remove the material from the mold and slice vertically through the center. Take a representative sample (100 grams minimum) from one of the cut faces, weigh immediately, and dry to a constant mass to determine the moisture content in accordance with AASHTO T 265, AASHTO T 217, or ASTM D 4643. The preferred method is AASHTO T 265, but one of the alternate methods may be used if necessary due to time constraints.

4.5. Thoroughly break up the remaining portion of the compacted material until it will pass a No. 4 sieve, as judged by eye, and add to the remaining portion of the test sample. Add a sufficient amount of water to increase the moisture content of the sample by approximately two percentage points, and repeat the above procedure for each increment of water used. Continue this series of determinations until there is either a decrease or no change in the unit mass of the compacted soil.

5. METHOD 2 PROCEDURE: (Modified from AASHTO T 99 METHOD C)

5.1. Weigh a minimum of 5000 grams of material; maintain the same percentage ratio of plus No. 4 and minus No. 4 material in the moisture-density sample as in the original field sample. The percentage of material retained on the 3/4" shall be replaced with material passing the 3/4" and retained on the No. 4 sieve. Material for replacement shall be taken from the remaining portion of the sample.

5.2. Mix the material and add sufficient water to dampen to approximately four percentage points below optimum moisture content. Compact the material in a 4-inch mold as in Method 1. In trimming the compacted specimen, holes may develop by removal of coarse particles; these may be patched with fine particles. Weigh the mold and moist material and determine the wet density as in Method 1.

5.3. Remove the material from the mold and slice vertically through the center. Take a representative sample from one of the cut faces and weigh immediately. Determine the moisture content in accordance with AASHTO T 265. The moisture content sample shall weigh approximately 500 grams.

5.4. Thoroughly break up the remaining portion of the compacted soil and return to the sample being tested. Add sufficient water to increase the moisture content by approximately two percentage points. Repeat the above procedure for each increment of water added. Continue this series until there is either a decrease or no change in the unit mass of the compacted material.

Note 6: Use only the 500-gram moisture sample from the first point and the entire compacted sample of the last point and average the moisture content to the points in between.

6. METHOD 3 PROCEDURE: (Cement Treated Sandstone)

6.1. Sieve an adequate quantity of representative sandstone aggregate over a 1" sieve and discard any portion retained. (Approximately 30 kilograms of 1" material should suffice to perform a 5 point proctor, if required, while using a separate and new sample for each compaction test.)

6.2. Select a representative sample of 6000 grams from the material prepared in 6.1 and add 300 grams of cement and mix thoroughly. Add water and mix thoroughly to dampen to approximately four percentage points below estimated optimum moisture content. Compact the aggregate-cement mixture as in Method 1 except use the 6-in. mold and 56 blows per layer. Following compaction remove the extension collar; carefully trim the compacted material flush with the top of the mold. In trimming the compacted specimen, holes may develop by removal of coarse particles; these may be patched with fine particles. Weigh the mold inclusive of the compacted material in kilograms to the nearest 5 grams, or weigh in pounds to the nearest 0.01 lb. For molds conforming to tolerances given in Section 2.1.2 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, or by 0.0294 where the weights are determined in grams, and record the result as the wet density, W_1, in pounds per cubic foot, of compacted material. For used molds out of tolerance by not more than 100 percent (2.1.3), use the factor for the mold as determined in accordance with Section 8 (Calibration of Measure), AASHTO T 19.

6.3. Remove the material from the mold and weigh immediately. Place the entire compacted specimen in an oven and dry to a constant weight to determine the moisture content in accordance with AASHTO T 255.

6.4. Using a new portion of aggregate each time (6000 grams) repeat 6.2 and 6.3 for each determination while adding water in approximately 2% increments (120 grams). Continue adding water in increments and compact until there is either a decrease or no change in the weight of the compacted aggregate plus mold.

Note 7: Due to the nature of sandstone material to degrade under repeated compaction, it is considered essential that an entirely new sample be used each time material is compacted into the mold.

7. METHOD 4 PROCEDURE: (Stabilized Aggregate Base)

7.1. Combine in mix percentages representative samples of dry ingredients for the stabilized aggregate base to a sample weight of 6000 grams (a separate sample will be needed for each point desired using a new sample for each compaction test)

7.2. Add water and mix thoroughly to dampen to approximately four percentage points below estimated optimum moisture content. Compact the stabilized aggregate base mixture as in Method 1 except use the 6-in. mold and 56 blows per layer. Following compaction remove the extension collar; carefully trim the compacted material flush with the top of the mold.

In trimming the compacted specimen, holes may develop by removal of coarse particles; these may be patched with fine particles. Weigh the mold inclusive of the compacted material and determine the wet density according to the procedure described in Section 6.2.

7.3. Remove the material from the mold and weigh immediately. Place the entire compacted specimen in an oven and dry to a constant weight to determine the moisture content in accordance with AASHTO T 255.

7.4. Using a new portion of aggregate each time (6000 grams) repeat 7.2 and 7.3 for each determination while adding water in approximately 2% increments (120 grams). Continue adding water in increments and compact until there is either a decrease or no change in the weight of the compacted aggregate plus mold.

8. CALCULATIONS AND REPORT:

8.1 Calculate the moisture content and the dry unit weight of the material as compacted for each trial, as follows:

$$M = \frac{A - B}{B - C} X\ 100$$

$$W = \frac{W_1}{M + 100} X\ 100$$

where:

M = percentage of moisture in the specimen based on oven dry weight of material.
A = weight of container and wet material.
B = weight of container and dry material.
C = weight of container.
W = dry density of compacted material in lb/ft^3.
W_1 = wet density of compacted material in lb/ft^3.

8.2. The formulas in subsection 8.1 shall be used to determine the moisture and corresponding dry density of each of the compacted samples. The dry densities in lb/ft^3 of the material shall be plotted as ordinates and corresponding moisture contents as abscissas. Typical test results and graphs are presented in Figures 1 and 2.

8.3. When the densities and corresponding moisture contents for the material have been determined and plotted as indicated above, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "Optimum Moisture Content" of the material under the above compaction.

8.4. The oven-dry mass per cubic foot of the material at the optimum moisture content shall be termed "Maximum Dry Density" under the above compaction.

NOTE 8: The dry mass (in grams) for each compacted sample may be plotted rather than plotting the actual density in pounds per cubic foot. After the curve is produced the maximum dry mass can be determined from the peak of the curve and converted to maximum dry density.

9. REPORT:

9.1. Method used (Method 1, 2, 3, or 4).

9.2. Optimum moisture as a percentage to the nearest whole number.

9.3. Maximum dry density to the nearest lb/ft^3.

9.4. For Method 2 report the amount of compacted material retained on the No. 4 sieve to the nearest percent.

9.5. Method used to determine moisture content (AASHTO T 265, AASHTO T 217, ASTM D 4643, or AASHTO T 255).

10. PROCEDURE FOR FIELD CORRECTION OF MOISTURE-DENSITY TEST RESULTS FOR VARIATIONS IN PERCENT RETAINED ON THE No. 4 SIEVE:

10.1. This procedure generally conforms to AASHTO T 224 and provides a means to adjust or correct the standard maximum dry density (Proctor density) of soil-aggregate mixtures if the percent retained on the No. 4 sieve is different for the field material than for the material on which the Moisture-Density test was run.

~~10.2. The use of the nomograph shown in Figure 3 to determine the adjusted maximum dry density is relatively simple. The first step is to plot the maximum dry density obtained from the Proctor test and the percent retained on the No. 4 sieve. Next, the bulk specific gravity of the material retained on the No. 4 sieve is plotted (if the specific gravity is unknown, a value of 2.65 may be assumed). Subsequently, the two points are connected with a straight line and, if necessary, the line is extended to intersect the vertical line representing the percent retained on the No. 4 sieve in the material in the field. From this point a line is projected horizontally to the abscissa. The value where the horizontal line crosses the abscissa is the adjusted standard maximum dry density. Examples are presented in Figure 4.~~

APPROVED _____

Director
Division of Materials

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